(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
5 April 2001 (05.04.2001)

PCT

(10) International Publication Number
**WO 01/23707 A1**

(51) International Patent Classification[7]: E21B 43/40

(21) International Application Number: PCT/NO99/00298

(22) International Filing Date: 29 September 1999 (29.09.1999)

(25) Filing Language: Norwegian

(26) Publication Language: English

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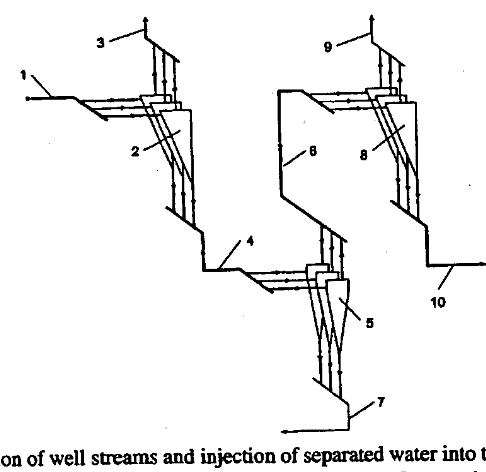
(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

**Published:**
— *With international search report.*
— *With amended claims.*

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

# (54) Title: DOWNHOLE SEPARATION DEVICE




**(57) Abstract:** A device for separation of well streams and injection of separated water into the wellbore has been described, which device is arranged in a wellbore, and which device comprises at least three stages of separation, each stage of separation comprising a hydrocyclone group (2, 5, 8), where each hydrocyclone group comprises one or more hydrocyclones connected in parallel, and where a well stream (10) comprising an oil fraction, a water fraction, a sand fraction and possibly a gas fraction is led to a first hydrocyclone group (2) for separation into an oily stream (3) and a stream (4) containing oil residue, sand and water, which stream (4) is led to a second hydrocyclone group (5) for separation into an oil and water-containing stream (6) and a sand-containing stream (7), which stream (6) is led to a third hydrocyclone group (8) for separation into an oily stream (9) and a water-containing stream (10), which water-containing stream (10) is injected into a suitable area of the reservoir through the wellbore. The separation device may be combined with various other separators and process equipment.

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Downhole separation device

The present invention relates to a downhole separation device for separation of well streams according to the introduction to Claim 1.

When oil and gas is produced from underground reservoirs, the pressure in the reservoir will normally decrease as the oil and/or gas well is depleted. As such, it will gradually become more difficult to retrieve the oil and/or gas. In order to counter this pressure reduction, water and/or gas is normally injected back into the reservoir in order to maintain the pressure, so as to increase the yield from the well.

The water and/or gas that is injected back into the well is normally separated from the well stream by means of separation devices installed at the surface or in the well.

Due to the loss of pressure that occurs across the various stages of the separation devices, the use of pumps is normally required, either to bring the various streams up from the well and/or to inject the separated water back into the reservoir. The pump(s) may be installed upstream of the actual separation stages, or the pump(s) may be installed downstream of the separation stages. In technical literature, a system incorporating pumps upstream of the separation stages is termed a "push-through" system, whereas a system incorporating pumps downstream of the separation stages is termed a "pull-through" system.

The separation process in a "pull-through" system will be more efficient than in a "push-through" system, as the well stream avoids going through the vigorous mixing and blending that takes place in a pump that located upstream of the separation stages.

In addition to the oil, water and possibly gas that occurs in the well stream, it will also contain sand and small rock fragments. This sand may cause severe wear and abrasion in separators, pumps and other equipment, hence it is of great importance that this sand be removed. In addition, the sand, which will naturally follow the flow of water that is to be injected into the reservoir, will tend to plug the pores in this reservoir, thereby reducing the injectivity.

Separation by means of filters and the disposal of separated water in the well has been described in US Patents 4,241,787 and 4,296,810.

Separation by means of hydrocyclones connected in series (dual stage) has been described in GB 2,191,120.

Gravity separation in a compartment in the well has been described in GB 2,194,572.

Separation of well streams by means of static and dynamic centrifugal systems has been described in GB 2,194,572.

Cyclone separation and injection into deviated wells has been described in US 5,711,374.

Single stage cyclone separation with two pumps provided downstream of the separation unit ("pull-through") has been described in US 5,296,153.

Dual stage cyclone separation, pump feeding, recirculation and pumping to the surface is known from WO 98/02637.

A "push-through" separator with fluid driven pumps discharging to the injection zone is known from WO 98/13579.

"Push-through" separation downhole with sand removal, where the sand is brought to the surface, is known from L. Danyluk, R.C. Chachula & S.C: Solanki: "Downhole 3-phase separation utilizing both ESP and PCP pumping systems", PanCanadian 1998 (SPE Paper 49053).

Removing sand from the well stream and bringing it to the surface has been described in the literature, but not in combination with multistage "pull-through" systems.

Thus, dual stage separation devices for well streams have been described before, but not combined with sand removal. Such systems are advantageous when compared with

single stage units, as they are able to handle incoming well streams with a lower water content (typically > 50%), whereas single stage units can only handle well streams with higher water contents (typically> 80%).

The object of the present invention is to solve the problems associated with wear in pumps and other process equipment, and to prevent a reduction in the injectivity of the reservoir.

This is achieved by means of a device for separation of well streams and injection of separated water into the wellbore, which device is arranged in a wellbore, characterised by the system comprising at least three stages of separation, each stage of separation comprising a group of hydrocyclones, where each group of hydrocyclones comprises one or more hydrocyclones connected in parallel, and where a well stream comprising an oil fraction, a water fraction, a sand fraction and possibly a gas fraction, is led to a first group of hydrocyclones for separation into an oily stream and a stream containing oil residue, sand and water, which stream is led to a second group of hydrocyclones for separation into a stream containing oil and water and a stream containing sand, the first of these streams being led to a third group of hydrocyclones for separation into an oily stream and a stream containing water, which is injected into the hydrocarbon-containing reservoir through the wellbore.

The device may also comprise a liquid/gas separator upstream of the separation device, for separating gas from the well stream, this separator preferably being a hydrocyclone.

The hydrocarbon-containing stream from the first stage of separation, the sand-containing stream from the second stage of separation and the hydrocarbon-containing stream from the third stage of separation are combined and led out of the well as a combined stream, the pressure of the streams being equalised by means of flow restrictions, if necessary, and the stream containing water from the third stage of separation is injected into a suitable formation zone in the well.

The device may also comprise a gravity separator arranged upstream of the device, for separating hydrocarbons from the well stream.

The device may also comprise a pump for pumping the water-containing stream from the third stage of separation down to the reservoir, which pump is preferably connected to a hydraulic motor (turbine) driven by a stream of separated water or pressurised seawater, the outlet stream from the hydraulic motor and the outlet stream from the pump being combined and led to the injection area as a combined stream.

The hydrocarbon-containing stream from the third stage of separation may be recirculated back to the inlet stream to the first stage of separation by means of a pump that is connected to a hydraulic motor (turbine) driven by the water-containing stream from the third stage of separation.

According to a particular embodiment of the invention for use with well streams with a high water cut (> 80%), the separation device comprises at least two stages of separation, each stage of separation comprising a group of hydrocylones, where each group of hydrocyclones comprises one or more hydrocyclones connected in parallel, and where a well stream containing an oil fraction, a water fraction and possibly a gas fraction is led to a first group of hydrocyclones for separation into a hydrocarbon-containing stream and a stream containing oil residue, sand and water, the latter of these streams being led to a second group of hydrocyclones for separation into a water-containing stream, which stream is injected into the reservoir, and the sand-containing stream is combined with the hydrocarbon-containing stream from the first group of hydrocyclones and led out of the well.

According to a further, preferred embodiment of the invention, the separation device comprises a gravity separator that separates the well stream into a hydrocarbon-containing stream and a water-containing stream containing water, hydrocarbon residue and sand, the water-containing stream being led to a first group of hydrocyclones comprising one or more hydrocyclones connected in parallel, for separation into a sand-containing stream and a water-containing stream, which water-containing stream is led to a second group of hydrocyclones comprising one or more hydrocyclones connected in parallel, for separation into a hydrocarbon-containing stream and a water-containing

stream, which water-containing stream may be injected into a suitable area of the reservoir.

The following will explain the invention in more detail, with reference to the accompanying drawings, in which

Figure 1 shows the basic embodiment of the separation device according to the present invention;

Figure 2 shows an embodiment of the separation device shown in Figure 1, in which a gas-liquid separator is included upstream of the separation device;

Figure 3 shows an embodiment of the separation device shown in Figure 1, in which the hydrocarbon stream and the sand-containing stream are led out of the well together;

Figure 4 shows an embodiment of the separation device shown in Figure 1, in which a gravity separator has been provided upstream of the separation device;

Figure 5 shows an embodiment of the separation device shown in Figure 1, in which a hydraulic pump has been provided downstream of the separation device;

Figure 6 shows an embodiment of the separation device shown in Figure 1, with recirculation of the water-containing hydrocarbon stream;

Figure 7 shows a simplified embodiment of a separation device for use with well streams with a high water cut (> 80%); and

Figure 8 shows a simplified embodiment of the separation device shown in Figure 4.

Figure 1 shows a basic embodiment of the downhole separation device according to the present invention. This embodiment is particularly suitable for an oil producing well, where the gas content is relatively low. The device shown consists of three stages of

separation, each consisting of a group 2, 5, 8 of hydrocylones, each group containing one or more hydrocyclones connected in parallel.

A well stream 1 containing water, hydrocarbons and sand is led to a first stage of separation in the form of a hydrocyclone group 2 consisting of one or more hydrocyclones connected in parallel. In this stage, the well stream is separated into a relatively clean oil stream 3 exiting via the overflow of the hydrocyclones and a stream 4 containing water, sand and oil residue exiting via the underflow of the hydrocyclones.

The stream 4 is led to the second stage of separation, which consists of a hydrocylone group 5 containing one or more hydrocylones connected in parallel. The stream 4 is separated into a stream 6 containing non-sandy water and some oil, and a stream 7 containing sand and water. The pressure of the stream 7 is equalised, and the stream may be led out of the well with the oil stream 9 from the third stage of separation.

The stream 6 is led to a third stage of separation consisting of a hydrocyclone group 8 containing one or more hydrocyclones connected in parallel. Here, the oil residue is separated from the water, and the oily stream 9 is led out of the well, while the cleaned water stream 10 is injected into the well or led out of the well.

Figure 2 shows an embodiment of the separation device, adapted especially to well streams containing gas. Here, the well stream 11 is first led to a gas-liquid separator 13, in this case a gas-liquid cyclone, in which the gas is separated out as a stream 12 and led out of the well, while the remaining well stream 1 containing oil, water and sand continues to the first stage of separation, described above in connection with Figure 1. By removing the gas from the well stream, the subsequent separation will be more efficient, as the gas will not influence the performance of the cyclone group 2.

Figure 3 shows a version of the separation device shown in Figure 1, in which the oily stream 3 from the first stage of separation 2, the oily stream 9 from the third stage of separation 8 and the sand-containing stream 7 from the second stage of separation 5 are combined and led out of the well as one stream 14. Due to the pressure drop across each stage of separation, pressure-reducing devices in the form of flow restrictions have been

placed in the oily stream 3 and in the sand-containing stream 7, that is15 and 16 respectively, so that the pressure of streams 3, 7 and 9 will be approximately equal when they are combined to form stream 14.

In a downhole separation device, each cyclone element will be subject to different operating conditions caused by varying pressure drops in the manifolds. The cyclone elements are arranged in-line across a relatively long unit, where the overflow and the underflow are fed to channels for fluid transport. The fluid flow in these manifold channels increases, as the feed from each cyclone element accumulates. This will bring a change in the pressure drop along the channel, which again results in uneven fluid loading and flow distribution for the cyclones, and causes undesired variations in performance. In order to counteract this situation, the cyclone elements have been adjusted separately by varying the performance characteristics for the individual cyclone, thus making it possible to maintain a constant and optimum pressure difference ratio for each cyclone element. Such an adjustment may be performed by altering the vortex finder opening or the diameter of the underflow opening.

Alternatively, the oily stream 9 from the third stage of separation 8 may be pressurised and recirculated (not shown) to the inlet stream 1 to the first stage of separation 2 in order to achieve a cleaner oil stream 14, which is led out of the well. This may be carried out by use of a pump or an ejector (not shown).

If, in addition, this embodiment includes a gas-liquid cyclone (shown as 13 in Figure 2) upstream of the first stage of separation, the separated gas may either be combined with the above-mentioned stream 14 or alternatively be led out of the well separately.

Figure 4 shows a further embodiment of the separation device according to the present invention.

This embodiment is particularly suitable in cases where the water content in the well stream is relatively low, i.e. the well stream is oil-continuous. In this, a gravity separator 17 is provided upstream of the first hydrocyclone group 2. In the gravity separator 17 most of the oil is removed as stream 18, and the remaining stream 1, consisting of

water, oil residue and sand, continues to the second stage of separation as described for Figure 1. This embodiment will result in a cleaner oil phase and a water phase that is clean enough to be injected.

Figure 5 shows an embodiment of the separation device according to the present invention as it is shown in Figure 3, in which the oil phase and the sand are combined before being carried to the surface. In the embodiment shown in Figure 5, a pump 20 is provided downstream of the separation device for injection of the water stream 10 into the reservoir. This pump 20 is connected to a hydraulic motor (turbine) 21, which is driven by a water stream 22. This water stream 22 may for instance come from a separation device on a platform, or it may be seawater that is pumped into the borehole. The outlet stream 23 from the motor 21 is combined with the water stream 24 from the pump 20, and injected into the well as a combined stream 26.

Placing the pump 20 downstream of the separation device ensures that sand is separated out upstream of the pump. This ensures that the pump is not subjected to abrasion and wear, as is often the case with several of the known solutions.

Figure 6 shows an embodiment of the separation device shown in Figure 3. Here, a motor (turbine) 27 has been provided downstream of the separation device, driven by the water stream 10. This motor 27 drives a pump 28 connected to the hydrocarbon-containing stream 9 from the third stage of separation, and the outlet stream 29 from the pump 28 is led back to the inlet to the separation device, where it is mixed with the well stream. The purpose of this arrangement is to achieve the lowest possible water content in the hydrocarbon stream 3. In addition, the sand-containing stream 7 can be mixed with the hydrocarbon-containing stream 3 from the first stage of separation and be led out of the well as a combined stream 14. In order to equalise the pressure of the streams 3 and 7, a flow restriction 15 may be provided in a similar manner to that described in connection with the embodiment shown in Figure 3.

Figure 7 shows a simplified embodiment of the separation device according to the present invention, for use with well streams with a high water cut (> 80%). This embodiment will consist of only two groups of hydrocyclones, the first of which

separates the well stream into an oily stream and a stream containing oil residue, sand and water. This latter stream continues to a second group of hydrocyclones for separation into a water-containing stream and a sand-containing stream, which water-containing stream is combined with the oily stream from the first group of hydrocyclones and led out of the well.

Figure 7 shows a simplified embodiment of the separation device shown in Figure 4, as the first hydrocyclone group 2 has been omitted. Here, the water-containing stream 4 from the gravity separator is directed straight to the second hydrocyclone group 5.

C l a i m s

1.

Device for separation of well streams and injection of separated water into the wellbore, which device is arranged in a wellbore,

c h a r a c t e r i s e d i n t h a t the device comprises at least three stages of separation, each stage of separation comprising a hydrocyclone group (2, 5, 8), where each hydrocyclone group comprises one or more hydrocyclones connected in parallel, and where a well stream (1) comprising an oil fraction, a water fraction, a sand fraction and possibly a gas fraction, is led to a first hydrocyclone group (2) for separation into a hydrocarbon-containing stream (3) and a stream (4) containing oil residue, sand and water, which stream (4) is led to a second hydrocyclone group (5) for separation into an oil and water-containing stream (6) and a sand-containing stream (7), which stream (6) is led to a third hydrocyclone group (8) for separation into an oily stream (9) and a water-containing stream (10), which water-containing stream (10) is injected into the hydrocarbon-containing reservoir through the wellbore.

2.

Separation device according to Claim 1,

c h a r a c t e r i s e d i n t h a t the device comprises a liquid-gas separator (13) upstream of the separation device, for separating out gas from the well stream (11), which separator (13) is preferably a cyclone.

3.

Separation device according to Claim 1,

c h a r a c t e r i s e d i n t h a t the hydrocarbon-containing stream (3) from the first stage of separation (2), the sand-containing stream (7) from the second stage of separation (5) and the hydrocarbon-containing stream (9) from the third stage of separation (8) are combined and led out of the well as a combined stream (14), which streams (3, 7) are regulated to the same pressure by means of flow restrictions (15, 16), if necessary, and where the water-containing stream (10) from the third stage of separation (8) is injected into a suitable formation zone in the well.

4.

Separation device according to Claim 1,
c h a r a c t e r i s e d i n t h a t the device comprises a gravity separator (17) provided upstream of the device, for separating out a hydrocarbon-containing stream (18) from the well stream (19).

5.

Separation device according to Claim 1 or 2,
c h a r a c t e r i s e d i n t h a t the device comprises a pump (20) for pumping the water-containing stream (10) from the third stage of separation (8) down into the reservoir, which pump (20) is connected to a hydraulic motor (turbine) (21) driven by a stream (22) of separated water or pressurised seawater, the outlet stream (23) from the hydraulic motor (21) and the outlet stream (24) from the pump (20) being combined and led to the injection area as a combined stream (26).

6.

Separation device according to Claim 3,
c h a r a c t e r i s e d i n t h a t the hydrocarbon-containing stream (9) from the third stage of separation (8) is recirculated back to the inlet stream (1) to the first stage of separation (2) by use of a pump (28) that is connected to a hydraulic motor (turbine) (27) driven by the water-containing stream (10) from the third stage of separation (8).

7.

Device for separation of well streams and injection of separated water into the wellbore, which device is arranged in a wellbore,
c h a r a c t e r i s e d i n t h a t the device comprises at least two stages of separation, each stage of separation comprising a hydrocyclone group (2, 5), where each hydrocyclone group comprises one or more hydrocyclones connected in parallel, and where a well stream (1) comprising an oil fraction, a water

fraction and possibly a gas fraction, is led to a first hydrocyclone group (2) for separation into a hydrocarbon-containing stream (3) and a stream (4) containing oil residue, sand and water, which stream (4) is led to a second hydrocyclone group (5) for separation into a water-containing stream (6), which water-containing stream (6) is injected into the reservoir, and the sand-containing stream (7) is combined with the hydrocarbon-containing stream (3) from the first hydrocyclone group (2) and led out of the well.

8.

Device for separation of well streams and injection of separated water into the wellbore, which device is arranged in a wellbore,

characterised in that the device comprises a gravity separator (17) that separates the well stream (19) into a hydrocarbon-containing stream (18) and a water-containing stream (4) containing water, hydrocarbon residue and sand, which water-containing stream (4) is led to a first hydrocyclone group (5) comprising one or more hydrocyclones connected in parallel, for separation into a sand-containing stream (7) and a water-containing stream (6), which water-containing stream (6) is led to a second hydrocyclone group (8) comprising one or more hydrocyclones connected in parallel, for separation into a hydrocarbon-containing stream (9) and a water-containing stream (10), which water containing stream (10) may be injected into a suitable area of the reservoir.

## AMENDED CLAIMS

[received by the International Bureau on 20 October 2000 (20.10.00); original claims 7 and 8 cancelled,original claims1 amended; remaining claim unchanged (1 page)]

6.

Separation device according to Claim 3,

characterised in that the hydrocarbon-containing stream (9) from the third stage of separation (8) is recirculated back to the inlet stream (1) to the first stage of separation (2) by use of a pump (28) that is connected to a hydraulic motor (turbine) (27) driven by the water-containing stream (10) from the third stage of separation (8).

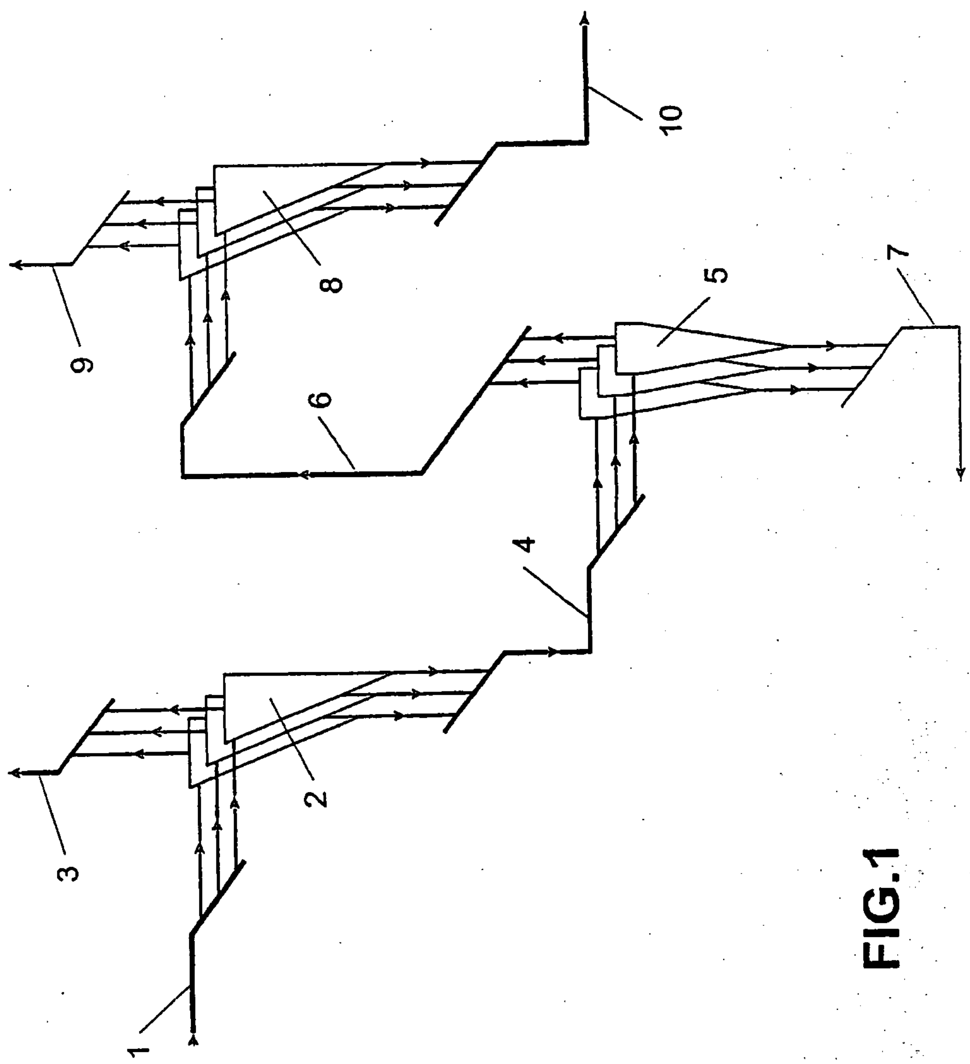


FIG.1

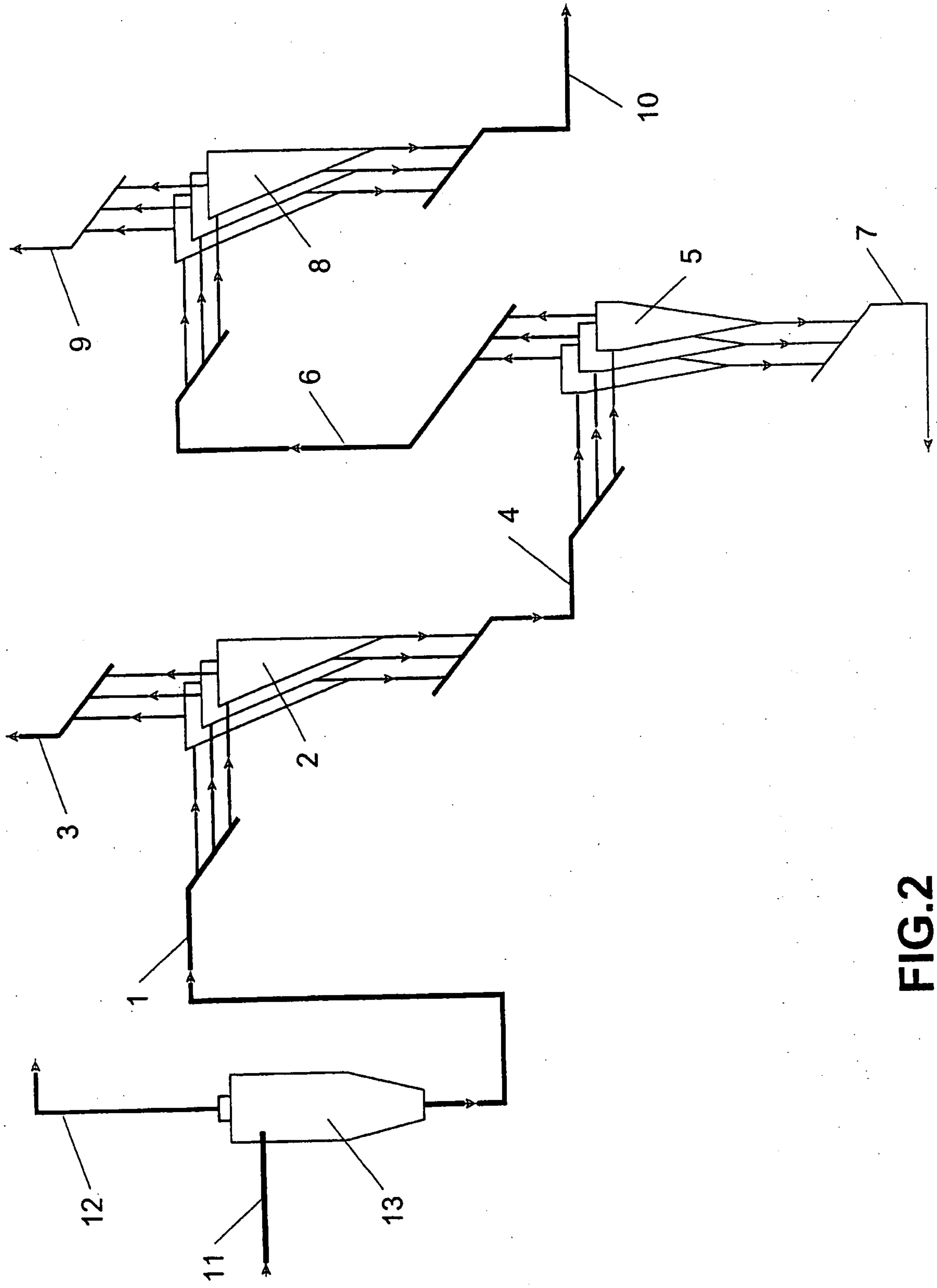


FIG.2

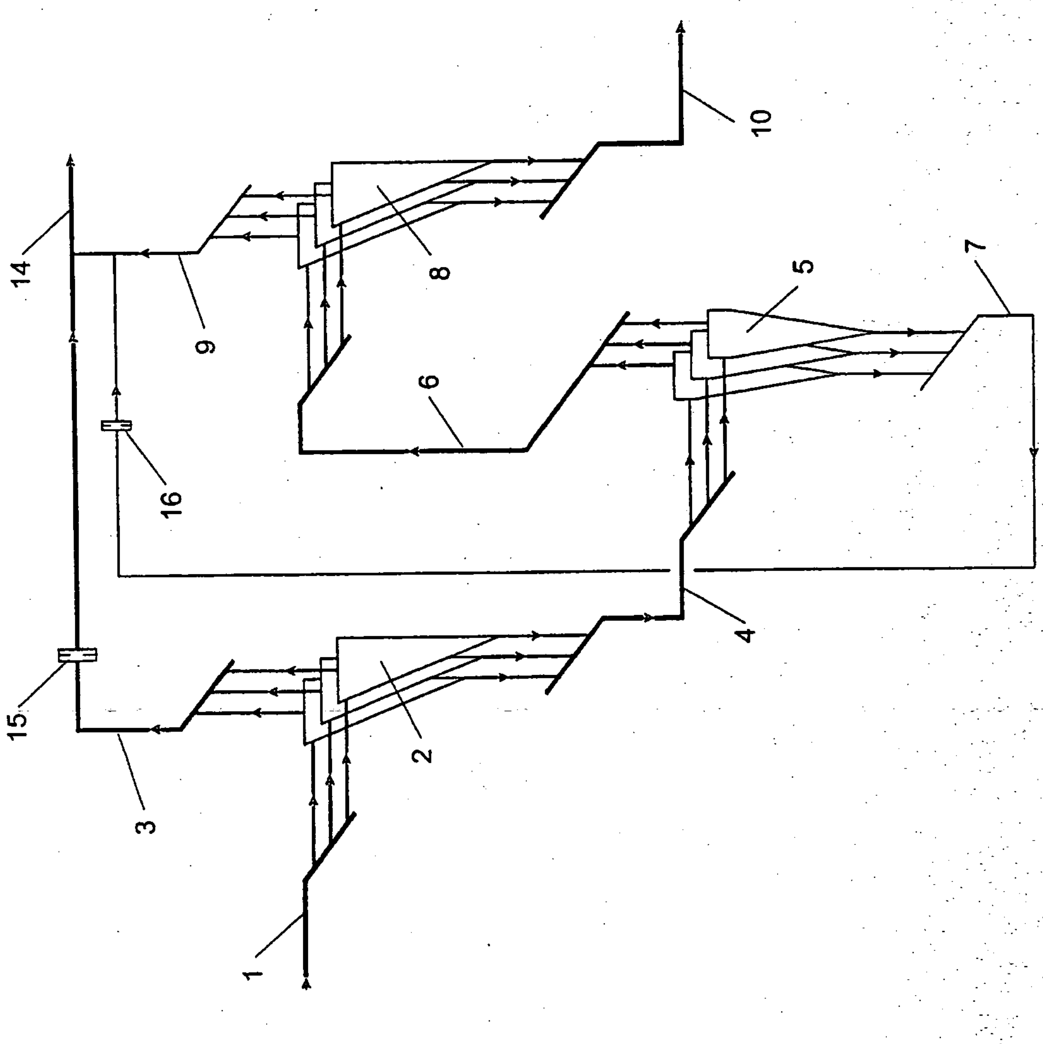


FIG.3

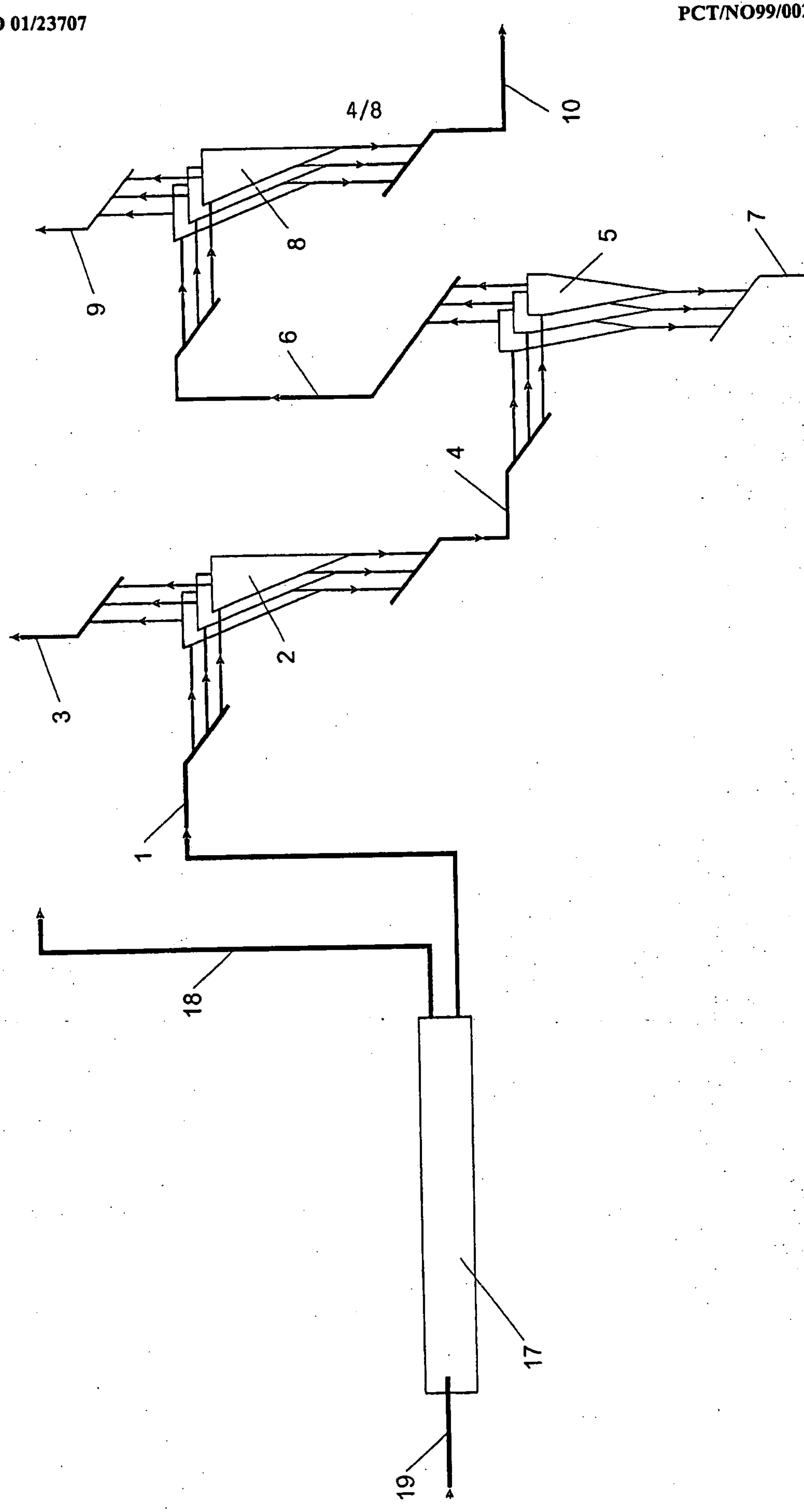


FIG.4

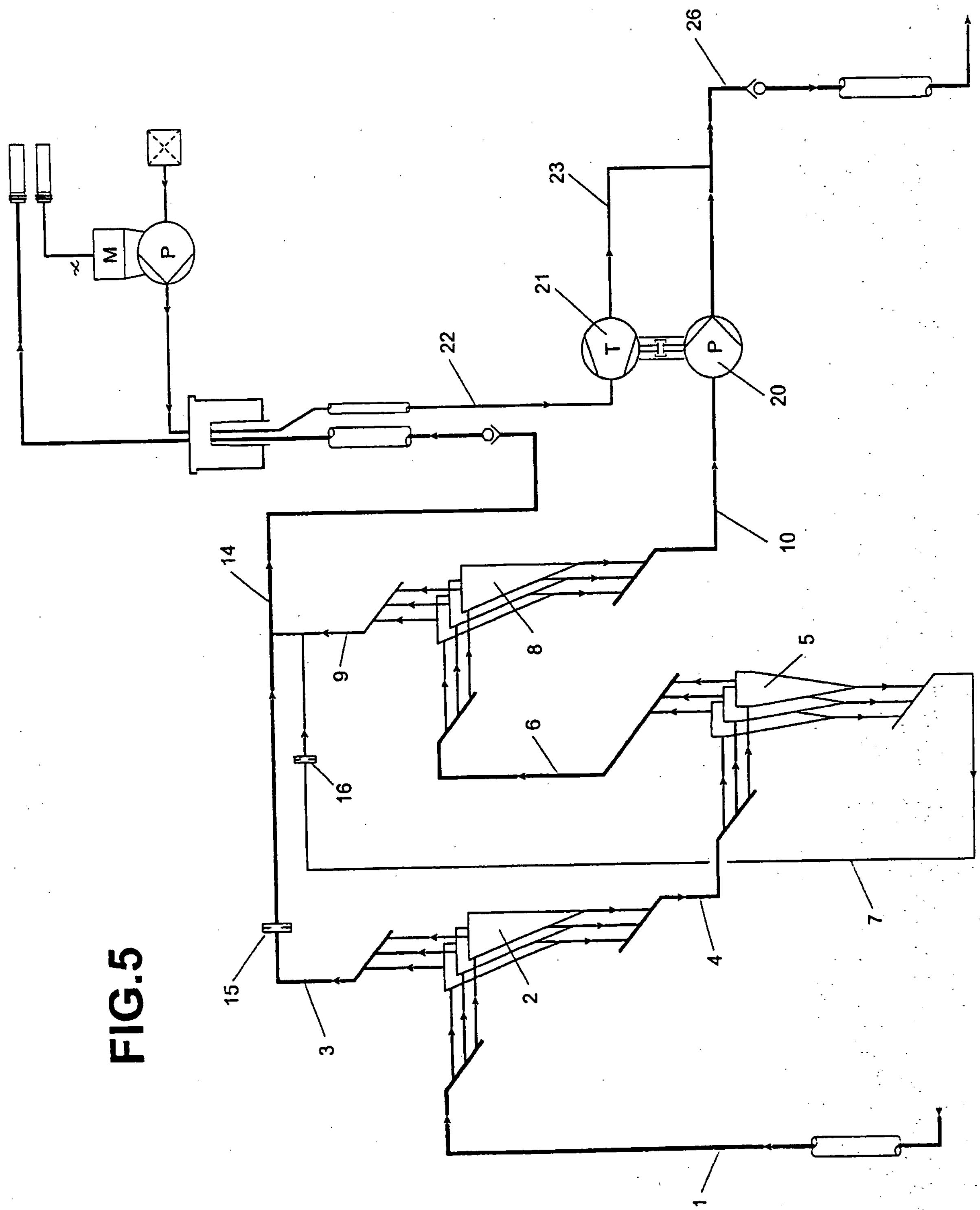


FIG.5

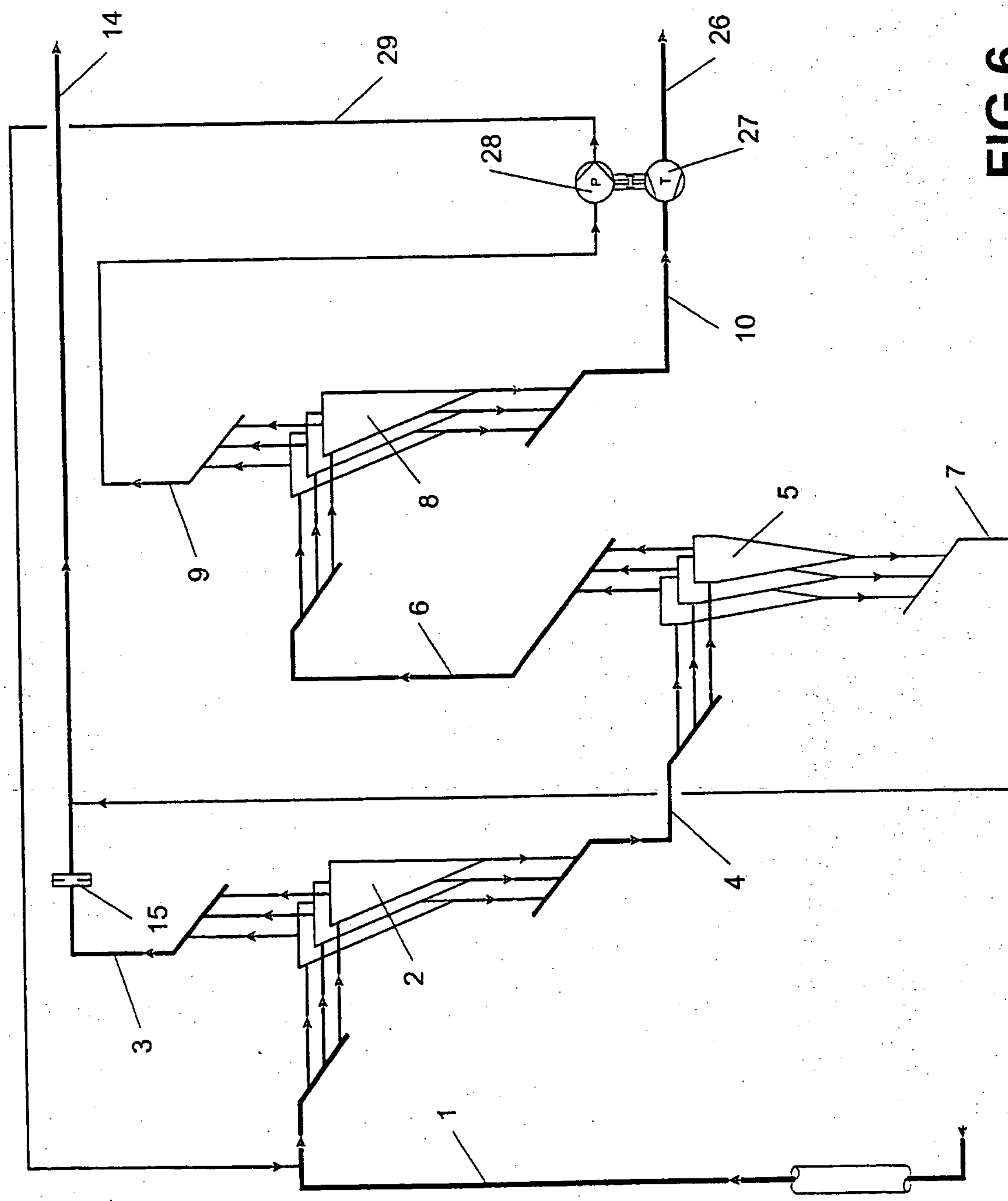


FIG.6

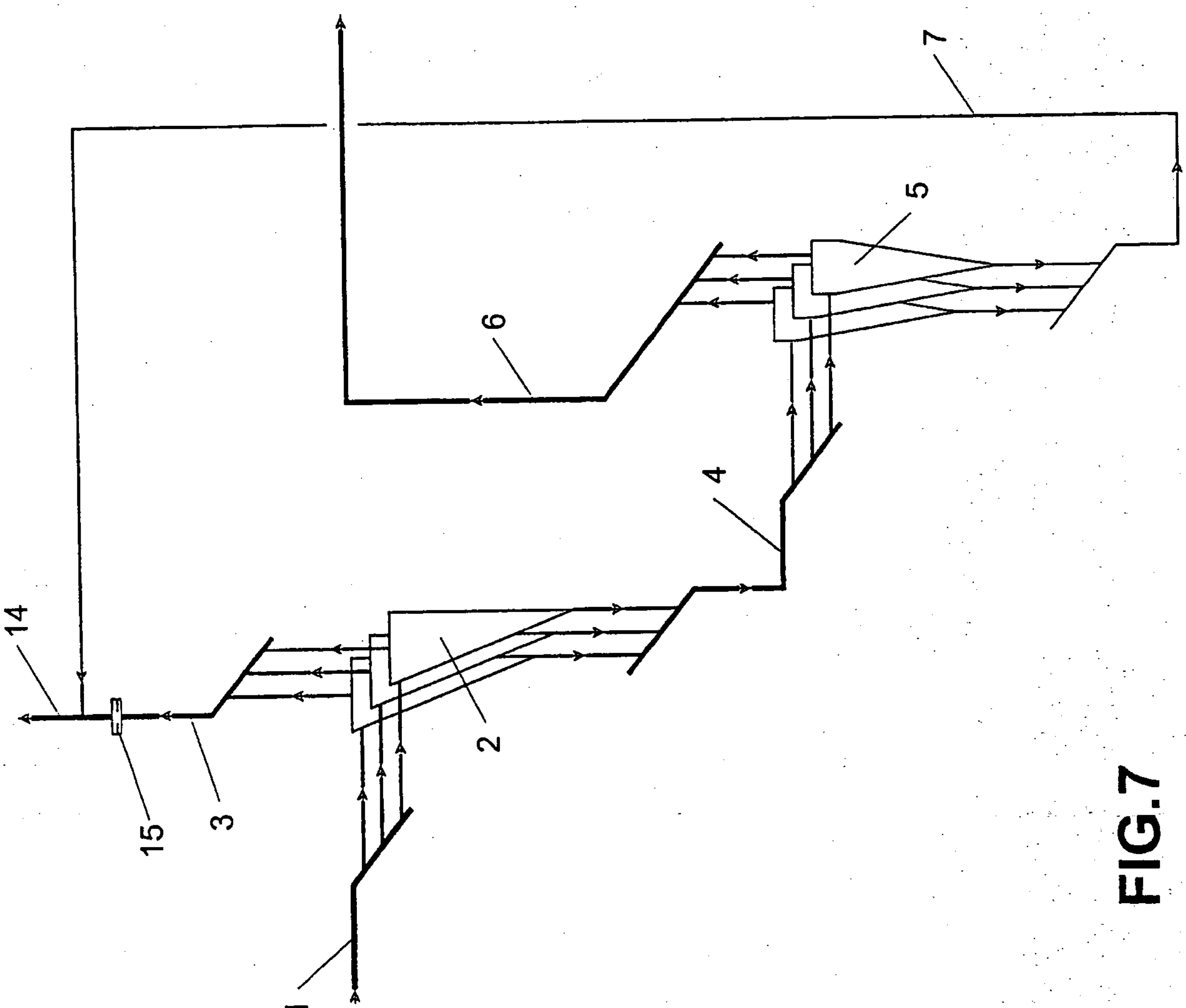


FIG.7

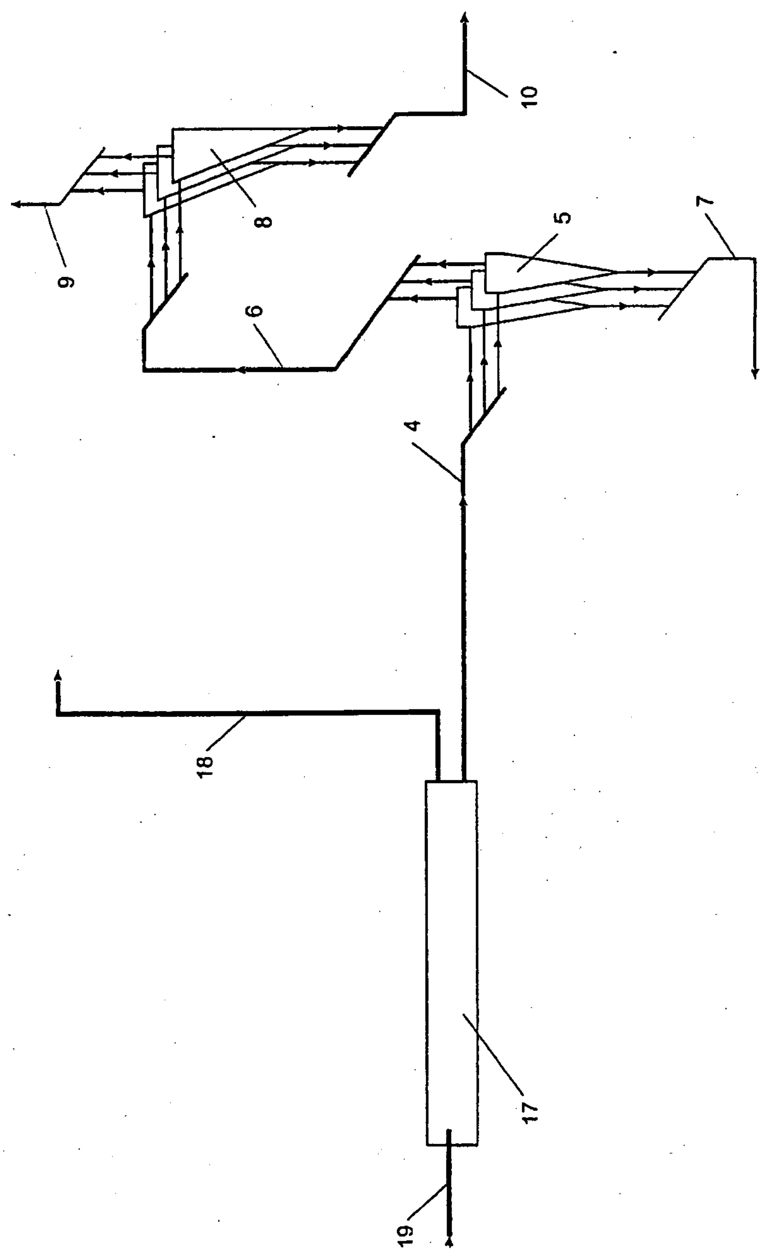


FIG.8

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 99/00298

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC7: E21B 43/40
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC7: E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | WO 9711254 A1 (BAKER HUGHES LIMITED), 27 March 1997 (27.03.97), page 3, line 26 - page 4, line 22 | 7 |
| Y | page 3, line 26 - page 4, line 22 | 1-4,8 |
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| A | WO 9940992 A1 (FRAMO ENGINEERING AS ET AL), 19 August 1999 (19.08.99) | 1-8 |
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| Date of the actual completion of the international search | Date of mailing of the international search report |
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# INTERNATIONAL SEARCH REPORT
Information on patent family members

02/12/99

International application No.
PCT/NO 99/00298

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| | | GB 9803183 D | 00/00/00 |